ACTIVITY REPORT

September 2003

Natural Gas & Oil Technology Partnership

Bringing Department of Energy national laboratories capabilities to the petroleum industry.

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Note: Natural Gas and Oil Technology Partnership projects are reported according to the following schedule:

January, March, May, July, September, November	**February, April, June, August, October, December**
Drilling, Completion, and Stimulation Technology Oil and Gas Recovery Technology Diagnostic and Imaging Technology	Upstream Environmental Technology Downstream Environmental Technology Natural Gas Technology

Natural Gas and Oil Technology Partnership on the World Wide Web: http://www.sandia.gov/ngotp/

Drilling, Completion, and Stimulation Technology

Downhole Seismic Source for Look-Ahead Pore Pressure Prediction While Drilling

(Halliburton and INEEL)

Highlights:

- Feasibility report completed.
- Savoy Field Research Facility selected for prototype testing.

The Capacitive Discharge Downhole Source (CDDS) and the Regenerative Combustion Seismic Source (RCSS) went through a second shallow well downhole source test series at the INEEL in preparation for October testing at the Rocky Mountain Oilfield Testing Center (RMOTC) out of Casper, WY. The tests included single well and cross well seismic profiling with single and multi-channel hydrophone strings.

Researchers are currently working with RMOTC personnel to identify a suitable well to conduct the last test series of this project. The well must be uncased, have a diameter greater than six inches, have a high water table, and a known lithology. The tests will include placing seismic sources, tube wave suppression equipment, and hydrophone strings in a single well to attempt seismic profiling. Testing should start during the last week of October. RMOTC will give us the opportunity to perform tests in an oil bearing formation.

Acoustic Telemetry (MWD) Drilling

(ABB, Electroacoustics Research Laboratory, Extreme Engineering, and SNL)

Highlight:

- Acoustic Telemetry report distributed.

The report entitled Acoustic Telemetry, which summarizes this project, is being distributed this week. There are extra copies, please call (505) 844-8920 if you want one. Researchers also attended a seminar at the University of Texas on a new method for transmitted waves through dispersive media like drill strings. This technique will have important oilfield applications.

Effects of Well Conditions on Post-Perforation Permeability

(Halliburton, Penn State, and LLNL)

Highlights:

- Extended our computational model to simulate the experiments in large cores used for the recently completed systematic experiments conducted at JRC.
- Ongoing efforts are aimed at calibrating the computational model to the range of experimental results provided by JRC and PSU.

Efforts to optimize well perforating strategies can benefit from improved understanding of the underlying mechanical and hydraulic processes and how they interact during and after shaped charge penetration of the formation. Combining detailed computational modeling with quantitative experimental investigations promises to shed new light on the dynamic evolution of permeability within perforated cores. High-resolution X-ray CT scanning of flow tests in cores perforated at Penn State University (PSU) has revealed the sub-core-scale details of the post-perforation permeability field. A series of standardized perforations and flow tests conducted at Halliburton's Jet Research Center (JRC) have provided additional core-scale data over a much wider range of well-bore conditions. Results from these experimental programs are being used to evaluate the computational perforation/permeability evolution model developed at LLNL. Integrating computational modeling with experiments in this manner promises to yield new insights into the mechanisms that control post-perforation permeability under down-hole conditions.

Lifetime Performance Monitoring of Synthetic Fiber Mooring Ropes

(Petroleum Composites, Puget Sound Rope, Shell, Whitehill Manufacturing, and ORNL)

No report received.

Automatic Flaw Detection and Identification for Coiled Tubing

(U of Tulsa, INEEL)

A new budget plan was developed and submitted to financial planning. This included a major re-planning of research due to the large cut in funding received from DOE. Research efforts have been restarted after this long funding lapse.

Researchers prepared for and attended the bi-annual Industrial Partner meeting hosted at the University of Tulsa, September 18, 2003. The presentations went well and were well accepted.

Per spring discussions with our research partner, Steve Tipton of the University of Tulsa (UT), a quick experiment was set up to collect signal integrity data with relationship to tube liftoff for CT-1 and CT-2 test tubes. This data was collected at 5, 6, and 7 amps, at a speed of 700 mm/s. This data should be reduced in October. Furthermore, initial correlations for defect detection for data taken during the spring of this project were received from UT. These correlations were based on spike height, width, etc. Nevertheless, some key correlation sets for CT-1 and CT-2 have not been received to date. An effort to reduce this data is currently underway.

Laboratory Study on Borehole Stability and Sand Production in Weakly Cemented Sand

(ChevronTexaco, Shell, and LBNL)

Pressure tests are continuing on the polyaxial (triaxial) X-ray transparent loading cell for sand production experiment.This cell applies three independent principal stresses to a rectangular block sample containing a single model borehole by hydraulic cylinder pumps. Due to leak problems of confining fluid under pressure, the cell's sealing mechanisms were modified by adding additional seals and seal supports. These modifications were effective, and currently the cell itself shows no leak. There is still a very small amount of leakage from the confining jacket, although this may not be a problem for conducting experiments.

Low frequency acoustic measurements are being conducted on cemented sand samples for their elastic moduli. However, the current setup can measure elastic moduli at frequencies that may be too low (0.5 kHz to 3 kHz) for interpreting the acoustic logs from borehole measurements. To increase the frequency of measurement, another setup was built based upon the classical split Hopkinson bar device that measures the changes in the acoustic waves transmitted through a small core sample. Preliminary results indicated that the frequency range of measurement with this new device is 5kHz to 10 kHz

Development of Smart-Proppant Technology for Hydraulic FracturingTubing

(U of Tulsa and INEEL)

Representative microbiological systems selected for experimentation have been augmented by a volunteer culture that exhibits the capability to liquefy guar solutions at elevated temperatures. Once liquefied by the culture at 60°C, the guar remains liquefied even when cooled to room temperature. The organism(s) responsible for the liquefaction were obtained from the non-sterile incubation of a 3% guar solution at 60°C with no nutrient amendment. The culture has not been purified to the point of individual isolates, however, it has been grown in 500 ml cultures. Culture evaluation is continuing with respect to identity, nutritional requirements for large-scale culture, and separation on non-essential community members. The liquefaction of guar associated with this culture is superior to microorganisms purchased to date.

Application of High-Powered Lasers to Drilling and Completing Deep Wells

(Gas Technology Institute, Halliburton Energy Services, PDVSA, Parker Geosciences,Colorado School of Mines, and ANL)

Highlights:

- Test plan for the first team test session for fiscal year FY03 - FY04 finalized and pretest preparation is underway.
- Developing and fabricating safe containment enclosures started.

After interactive discussion among the team members, the work planning for fiscal year FY03 to FY04 is complete. Back in July, 2002, ANL's 1.6 kW Nd:YAG laser beam was applied on sandstone and shale samples to investigate multi-spot holes. The next team test session, scheduled for the last week of October 2003 at ANL, will be on CO_2 laser multi-spot drilling of rock. The main advantage of ANL's CO_2 laser is its high average power, up to 6 kW. High average power should reduce the number of total spots needed to cover a large diameter hole, resulting in a higher rate of penetration.

Pretest preparation for the session is underway, which primarily consists of installation and testing a rotary stage, development of motion control computer codes, and design and fabrication of safety enclosures. Safety enclosures for CO_2 and YAG lasers are needed to protect personnel and equipment while allowing testing of lenses, gas purge, and fiber designs on dry and saturated rock samples. The enclosure for the CO_2 laser is scheduled to be finished before the test session. The results of this effort should be available at the end of the next reporting period.

Publications

Z. Xu, and C. B. Reed, R. A. Parker, R. Graves, "Application of High Powered Lasers to Perforated Completions", International Congress on Applications of Laser & Electro-Optics, October 13 – 16, 2003, Jacksonville, Florida.

S. Batarseh and B. C. Gahan, R. A. Parker, Z. Xu, and C. B. Reed, "Rock Phase Control By Using High Power Laser For Production Enhancements", International Congress on Applications of Laser & Electro-Optics October 13 - 16, 2003, Jacksonville, Florida.

C. B. Reed, Z. Xu, R. A. Parker, B. C. Gahan, S. Bartarseh, R. M. Graves, H. Figueroa, W. Deeg, " Laser Rock Drilling for Oil and Gas Wells", American Association of Petroleum Geologists, 2003 Mid-Continent Section Meeting in Tulsa, Oklahoma, 2003.

Oil and Gas Recovery Technology

Measuring Sucker Rod Pump Parameters Downhole

(Harbison-Fischer, UT-Austin, and SNL)

Highlight:

- Instrumented pump for Texas Tech fabricated.

A pump instrumented with a compression chamber pressure transducer has been fabricated by Harbison-Fischer for Texas Tech. It is ready for assembly and will undergo functional testing.

Coupled Geomechanical Deformation, Fluid Flow, and Seismic Modeling

(ExxonMobil, Schlumberger, UT-Austin, and SNL)

No report received.

Direct Simulation of Near-Wellbore Mechanics

(ChevronTexaco, Halliburton, Schlumberger, Shell, MIT, NM Tech, and SNL)

Highlight:

- Several large 2-D DEM models with approximately 10,000 particles have been developed for the sanding simulations.

Research continued during this project period on the application of the 2-D code and the implementation of the 3-D code. In addition to the PI, project staff contributing during this period included graduate interns Dave Boutt (NMT), Dave Farrell (Clarkson), and Scott Johnson (MIT), as well as postdoctoral associate Erik Strack. Recent work has continued to focus on two activities: 1) the development and testing of 2-D model specimens for the sanding simulations; and 2) the integration of the 3-D fluid solver with the 3-D DEM code.

Several large 2-D DEM models with approximately 10,000 particles have been developed for the sanding simulations.The models have been constructed with different distributions of particle shapes to evaluate the effect of particle shape on the simulated sand production. Models with different consolidation stresses and cohesion are also being developed to determine the effect of these parameters on cavity stability and associated sanding rates. Several sanding simulations are currently running and initial results should be reported in the upcoming project period.

Validation work on the 3-D code is continuing. Initial results (reported in the previous period) for fluid flow and forcing on fixed solid bodies were encouraging; however, validations conducted during this period for moving solids exhibited some discrepancies from expected behavior.To isolate the source of these differences, the 3-D code is being compared to the previously validated 2-D code using idealized 2-D problems.

Well Integrity Assurance for Sub-Salt and Near-Salt Deepwater GoM Reservoirs

(BHP, BP Amoco, ChevronTexaco, ConocoPhillips, ExxonMobil, Halliburton, Kerr-McGee, Shell, and SNL)

Highlight:

- Single-company meetings were conducted at BHP and ExxonMobil in September to discuss salt-related issues.

A software tool for predicting time-to-closure for through-salt circular boreholes as well as time-to-contact and time-to-yield for elliptical through-salt boreholes is being developed. The tool is based upon a large number of non-linear wellbore scale finite element analyses conducted over ranges of depth, borehole pressure, and temperature conditions applicable to deepwater Gulf of Mexico fields. The tool will enable in-house application of the wellbore scale modeling to be applied in-house by industry partners to aid in well casing design.

An Integrated Approach to Assessing Seismic Stimulation

(Aera Energy, ASR, BP Amoco, ChevronTexaco, ConocoPhillips, Halliburton, Marathon, OGCI, Piezo Sona-Tool, Schlumberger, Shell, UC-Berkeley, LBNL, and LANL)

Preparations were made for another round of field monitoring at the Lost Hills oil fields. An existing tool was modified for simultanous measurements of pressure and ground motion. This was accomplished by adding a high sensitivity, broad band (1 hertz to 12 Khz) hydophone to a three component clamped geophone tool. The objective is to measure both the fluid pressure signal and the vibration of the matrix simultaneously at the same location. The first measurements will be in early October at the ChevronTexaco field and later at the Aera field site.The stimulation source will be the ASR pressure pulse device.

Modeling was carried out using the coupled fluid Lo-Sposito model using in-situ properties of diatomite. The results indicate that the maximum effect (pore expansion) should occur at low frequencies (10 to 50 hertz). Previous modeling using "generic" properties of sandstone indicated that maximum effect would be at 200-300 hertz. Previous monitoring at the Aera site found

that the ASR tool (in a well 43 feet from the source) had a peak amplitude at 200 to 300 hertz. The monitoring at the ChevronTexaco site will be in a well approximately 1000 feet from the source well.

Direct Quantification of Uncertainties Associated with Reservoir Performance

(ChevronTexaco and LANL)

A new algorithm, a moment-equation method based on Kahunen-Loeve decomposition (KLME), has been developed. This method is computationally more efficient than both Monte Carlo simulations (MCS) and the conventional moment-equation method (CME) which was proposed in the project. The KLME approach allows evaluation of higher-order terms that are needed for highly heterogeneous reservoirs. A detailed comparison was performed among these different methods in terms of computational efficiency and accuracy. The new development resulted in three manuscripts, two of which have been accepted by *SIAM Journal of Scientific Computing and Journal of Computational Physics*. The KLME method makes it possible to simulate flow and transport in large-scale heterogeneous reservoirs. 2-D computer codes are being extended to 3D.

Diagnostic and Imaging Technology

Inversion of Full Waveform Seismic Data for 3D Elastic Parameters

(Amerada Hess, ChevronTexaco, ConocoPhillips, Fairfield Industries, GX Technology, Marathon, Unocal, and SNL)

Project funding on hold, no report this month

Next-Generation Seismic Modeling and Imaging

(Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, ChevronTexaco, Conoco, Core Laboratories/Tomoseis, ExxonMobil, Fairfield Industries, Fugro Geoservices, GeoCenter, Geophysical Development, GX Technology, Marathon, Mitchell Energy, Paradigm Geophysical, PGS, Phillips, Shell, Unocal, Veritas DGC, WesternGeco, SEG, Stanford University, University of Houston, LANL, and LLNL)

Highlight:

- Elastic data computations continue in Marmousi model

Synthetic elastic seismic data are being computed in the challenging 2-D Marmousi II (elastic) model. The Marmousi II model was created by taking the original acoustic model and assigning elastic properties, extending the horizontal extent to 17 km, adding 500 m of water at the top, and adding multicomponent receivers along the sea floor and in a well embedded in the model.

Synthetic elastic seismic data are being computed with a shot grid of 25 m spacing. Synthetic data are being computed for two cases - a normal, reflecting boundary at the sea surface, and an absorbing boundary at the sea surface. In the first case, sea column multiples are expected to be strong. In the second, they will be suppressed. Comparison of the two data sets will help test the effects of multiple suppression in seismic processing. Synthetic data computations are about 90% complete for the absorbing boundary case.

Rapid Imaging of Interwell Fluid Saturations Using Seismic and Multiphase Production Data

(BP Amoco, ChevronTexaco, ConocoPhillips, ExxonMobil, JNOC, Landmark, RC2, Statoil, Tomoseis, Total-Fina-Elf, Texas A&M, and LBNL)

A paper was completed that describes a novel method for utilizing time-lapse pressure estimates to infer reservoir permeability variations. It has been accepted for publication in the journal *Geophysics*.

Another paper was presented at the SPE annual meeting in Denver, Colorado, entitled, "Reconciling Time-lapse Seismic and Production Data Using Streamline Models: The Bay March and Field, Gulf of Mexico". We were invited to present the results at the annual meeting of the Society of Exploration Geophysicists in Dallas in a special workshop, "Seismic Determination of Pressure, Saturation, and Porosity".

The inversion of two-phase breakthrough times was compared to amplitude inversion using a quantitative measure of non-linearity. The amplitude inversion is at least two orders of magnitude more non-linear than travel time inversion. These results were also presented at the SPE annual meeting in Denver.

Offshore Oil Field Characterization with EM Methods

(Scripps, Texas A&M, and SNL)

Highlights:

- An new "black-box" Occam inversion engine was recently developed and tested on a controlled-source EM dataset (testbed data from a land-based survey).
- Progress was made during this reporting period in numerical modeling of the long period "coast effect".

Progress has been made in the two critical areas of this research program. The first area is algorithm development for geophysical inversion capabilities. A new "black-box" Occam inversion engine was recently developed and tested on a controlled-source EM dataset (testbed data from a land-based survey). This inversion engine is written in FORTRAN like its predecessor,but with the added benefit of exploiting dynamic memory allocation features now available in FORTRAN 90. Application of the engine to marine MT/CSEM data requires no modification of the Occam internals.

The second area of progress made during this reporting period is in numerical modeling of the long period "coast effect". Calculations of long-period regional-scale EM induction in the oceans reveals the presence of galvanic charge accumulations at the ocean-continent boundaries and their resulting polarization effects which plague MT data at low frequencies.

Innovative Wave-Equation Migration

(Advanced Data Solutions, Amerada-Hess, Applied Geophysics Services, Baker Atlas, BHP, ConocoPhillips, ExxonMobil, FairfieldIndustries, GX Technology, Petroleum GeoServices, Screen Imaging, Shell, TomoSeis, Unocal, Veritas DGC, and LANL)

Highlight:

- Project meeting held in Sugarland, TX

Fairfield Industries hosted the fourth project meeting in Sugar Land, Texas, on September 18, 2003. A total of 40 people representing 18 companies were present at the meeting. The companies include: AGS, Amerada Hess, BHP Billiton, ChevronTexaco, ConocoPhillips, CoreLab, ExxonMobil, Fairfield Industries, GDC, GXT, Parallel Data System, PGS, SeismicCity, Shell, Stanford University, Unocal, Veritas DGC, VSFusion.

Six presentations were presented describing work progress on wave-equation migration imaging during the past year. Topics presented included:

1) Developments in controlled-aperture wave-equation migration, which is a method for obtaining improved images in common-shot migration by limiting the region of the subsurface migration for each shot.

2) A new imaging condition producing images that can be more reliably interpreted to determine rock properties at an interface within the Earth.

3) Offset-domain wave-equation migration in which all shot gathers are migrated simultaneously in a manner that is intended to be computationally

more efficient than conventional shot-domain migration.

4) A novel approach for conducting 3-D wave-equation migration that has potential to produce better images than other approaches for offset-domain migration while maintaining the speed advantage of those methods.

5) 3-D wave-equation migration results of a large 3-D Gulf of Mexico common-shot dataset.

There was excellent interactive discussion about the work and the industrial participants showed great interest in the research work. They indicated that the 3-D wave-equation migration images of the Gulf of Mexico dataset are superior to those obtained using other wave-equation migration methods.

Testing and Validation of High-Resolution Fluid Imaging in Real Time

(DeepLook, KMS Technologies, KJT Enterprises, U of Wisconsin, LBNL, and SNL)

No report received.

Autonomous Monitoring of Production

(Aera Energy, ChevronTexaco, SteamTech Environmental Services, TomoSeis, and LLNL)

Between 10 and 17 September, a visit was made to the Hobbs, NM site to repair equipment damaged once again by lightning storms in the area. After repairs, data were taken for the northwest and southwest patterns. Procedures for lightning protection that had been worked out since the previous trip were implemented.

Meetings were held to review progress with the ChevronTexaco partners. Similar progress reports will be prepared for the other partners who were not able to attend the meetings in Texas and New Mexico. The possibility of using electrical resistivity tomography (ERT) results was considered to constrain the non-unique solutions that come from the reservoir operator's flow and transport simulations to understand and manage the field.

ERT data from the September surveys are being processed and have already yielded two important results. First, a means for minimizing telluric noise was demonstrated, and second, long term stability of the measurement system is ensured.

Anisotropic Properties of Compacted Clay-Rich Rocks

(BP Amoco, ChevronTexaco, ConocoPhillips, and LBNL)

Efforts during this reporting period continued with S-wave transducer fabrication, and installation. Assembly of the non-resonant 50 kHz S-wave transducers is nearing completion. Devices required for the uniaxial strain clay compaction tests, such as the linear variable displacement transducer holders and cutting devices to prepare the slot-shaped clay samples, were designed and fabricated. Testing continued with the 32 element 1 MHz P-wave phased array on a phenolite (an orthotropic commercial plastic) sample and the anisotropic elastic constant inversion code.

Realistic Anisotropic Velocity Estimation in Complex 3D Environments

(BP Amoco, ChevronTexaco, ConocoPhillips, Kerr-McGee, Shell, TomoSeis, and LBNL)

Based on the dispersion relationship for quasi-P(qP) or P waves in VTI media, an implicit finite-difference migration method was developed. In this method, the seismic wavefields are extrapolated by an implicit finite-difference extrapolator in depth. A Pade approximation with optimized coefficients

replaces the exponential operator. Since an implicit finite difference method was used to solve the one-way wave equation, this method is unconditionally stable. It is much faster than reverse time migration, and suitable for migration velocity analysis. As far as known, this method has not been published. The next step will be to develop a migration velocity analysis technique based on the new method.

It is well known that it is difficult to model structural dip and irregular interfaces using the conventional finite-difference method. Recently, Wright (2003, PhD thesis) proposed a radial basis function (RBF) finite difference method to solve partial differential equations (PDEs) in unstructured grids. This method has several advantages - no regular meshes are needed, it can model irregular boundaries, and it is easy to implement.

This method was used to solve Possion's and Laplace's equations. However, this method has not yet been demonstrated for solving wave equation problems. Work has begun to determine the applicability of this method for wave equation solutions. A finite difference code with RBFwas developed and tested with a regular mesh. Test comparisons between unstructured meshed and regular meshes are now beginning for dipping interface models.

Joint Geophysical Imaging

(ChevronTexaco, Core Laboratories, Electromagnetic Instruments, ExxonMobil, and SNL)

Highlight:

- This past month has seen the successful implementation of a 2-D electromagnetic inversion code for sea-bed logging.

This past month has seen the successful implementation of a 2-D electromagnetic inversion code for sea-bed logging. This code was also recently licensed to BP, and allows for testing the resolution of 2-D reservoir models using scalar workstation platforms. Good progress was also made on the 3-D EM inversion modeling and inversion code for sea-bed logging. Synthetic models demonstrate the codes capability to converge for long offset receiver data (offsets on the order of 5 kilometers), where significant differences (two orders of magnitude) are seen between observed and predicted data. In order to achieve convergence for long offset data it was necessary to incorporate a data-weighting scheme based on the reciprocal of the data measurement. Work is now focusing on testing the 3-D code over more complex reservoir geometries, constrained by seismic reflection data. Efforts are now underway to secure a field data set from Shell for testing the 2-D and 3-D inversion codes, and for imaging the fluid properties of offshore oil and gas reservoirs.

Partnership Office

The partnership anticipates funding in the 2004 fiscal year to be similar to 2003. Although this level of funding still represents a significant reduction compared to the previous five years, the partnership has started planning to move forward with a concentration on the highest impact projects. The partnership has made a commitment to fund the top new projects in the FY2003 review cycle in 2004. The laboratory representatives are currently working on several scenario's to facilitate these new starts. To accomplish these scenarios, the partnership will need to reduce some ongoing projects. The partnership office will clarify these scenarios for 2004 in the next monthly report.